Buffer layer development for coated conductors using the IBAD-MgO template

Quanxi Jia, Steve Foltyn, Paul Arendt, Terry Holesinger,
Randy Groves, Marilyn Hawley, Raymond DePaula,
Yates Coulter, Paul Dowden, Liliana Stan

Superconductivity Technology Center
Los Alamos National Laboratory

Buffer material plays a major role in determining the performance of YBCO films on metal substrates

Requirements for the buffer

- Structural compatibility - crystallographic lattice match between the HTS film and the template
- Thermal stability - stable in high temperature oxidizing environment
- Chemical stability - minimal chemical interaction between the buffer and adjacent layers
- Barrier capability - provide a sufficient barrier against interdiffusion

Buffer materials on MgO

- $SrTiO_3$ ($Ba_{1-x}Sr_xTiO_3$)
- CeO_2/YSZ
- $LaMnO_3$ ($La_{1-x}Sr_xMnO_3$)

Our goal – to develop a stable, effective, and single buffer layer on IBAD-MgO on Ni-alloy for coated conductors

Many unique properties of $SrRuO_3$ make it attractive for use in coated conductors

Pseudocubic perovskite $SrRuO_3$ (a = 3.93 Å)

Orthorhombic distortion $a/b = 1.006$, $c/(a^2 + b^2)^{1/2} = 1.000$

a = 5.573 Å, b = 5.538 Å, c = 7.856 Å

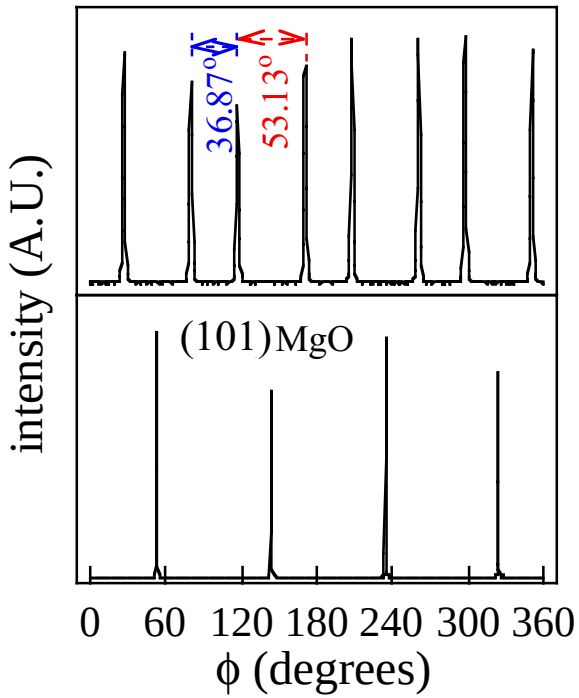
- Structurally and chemically compatible with YBCO and MgO
- Excellent diffusion barrier properties
- Good thermal stability
  - ✓ Compositionally stable at a temperature as high as 850 °C.
- High chemical corrosion resistance
  - ✓ Resistant to attack by strong acids

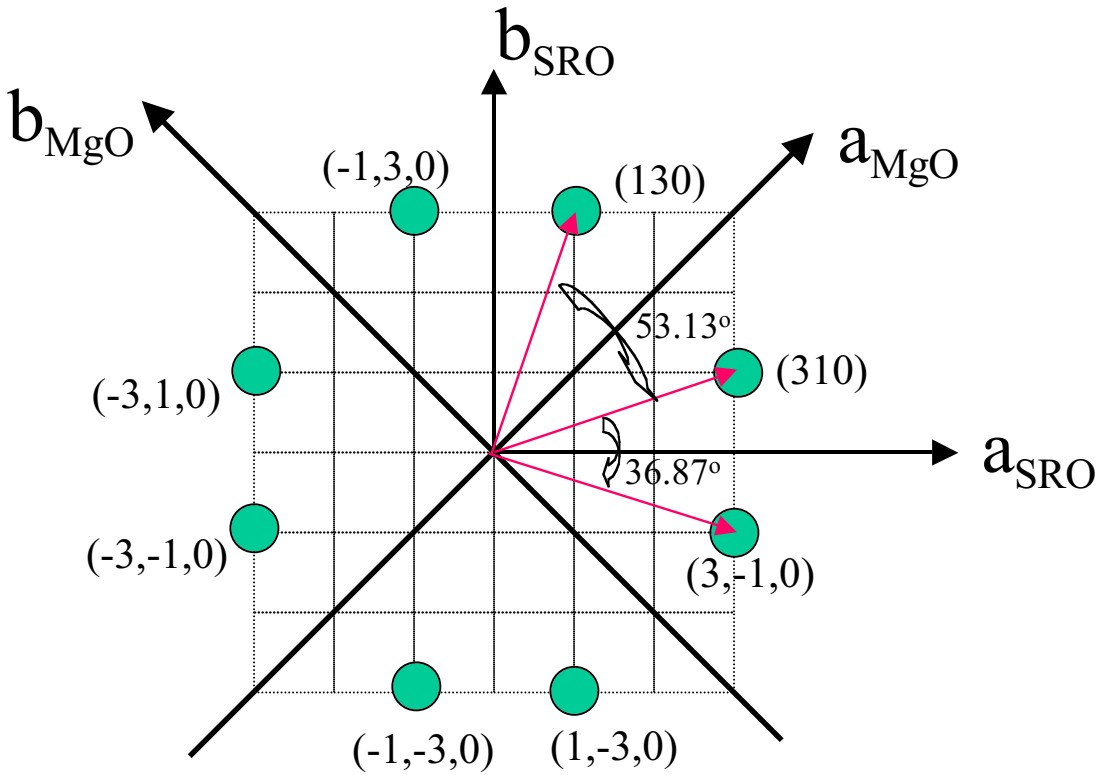
Successful growth of $SrRuO_3$ thin films and as a buffer layer for YBCO dates from the early days of HTS

- High crystalline quality epitaxial $SrRuO_3$ films on $SrTiO_3$ were demonstrated by AT&T Bell Labs (Eom *et al*., Science, **258**, 1766, (1992)).
- High quality YBCO films were obtained on structurally and chemically compatible $SrRuO_3/LaAlO_3$ substrates by LANL (Wu *et al*., Appl. Phys. Lett. **62**, 2434 (1993)).
- Epitaxial barriers of $SrRuO_3$ were used to fabricate high-temperature superconductor/normal-metal/superconductor Josephson junctions by Conductus Inc. (Antognazza *et al*., Appl. Phys. Lett. **63**, 1005 (1993)).
- Epitaxial YBCO films were deposited on single crystal MgO using $SrRuO_3$/Pt buffer layers by LANL (Tiwari *et al*., Appl. Phys. Lett., **64**, 634 (1994); US patent from LANL, # 5,470,668, Nov. 1995).

X-ray diffraction reveals that $SrRuO_3$ aligns perfectly on single-crystal MgO

ϕ-scans on (132) of $SrRuO_3$ and (101) MgO

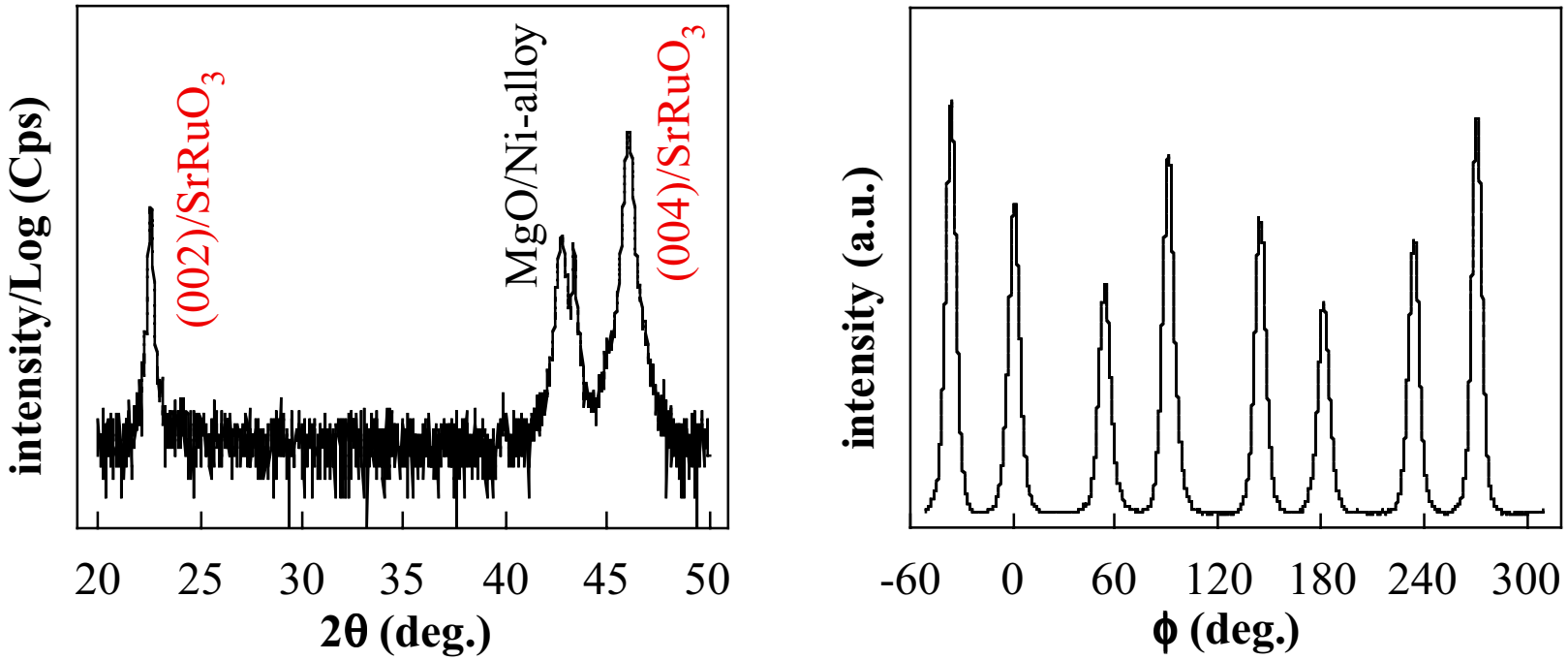




The reciprocal lattice points on (001) plane

$SrRuO_3$ grown on IBAD-MgO on Ni-alloy shows the same orientation relationship as that grown on crystal MgO

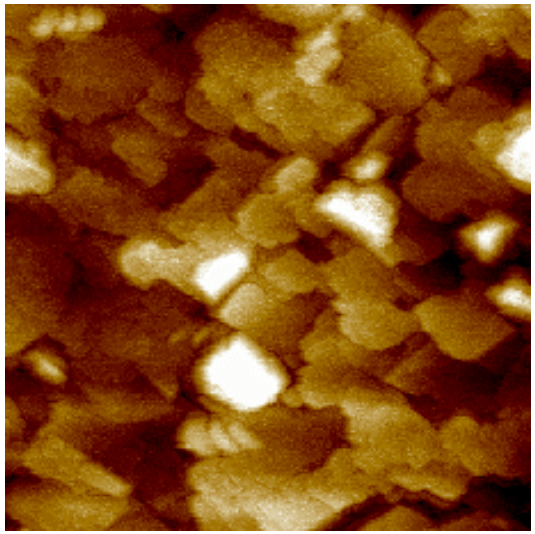
$(001)_{SRO}||(001)_{MgO}$; $<110>_{SRO}||<100>_{MgO}$



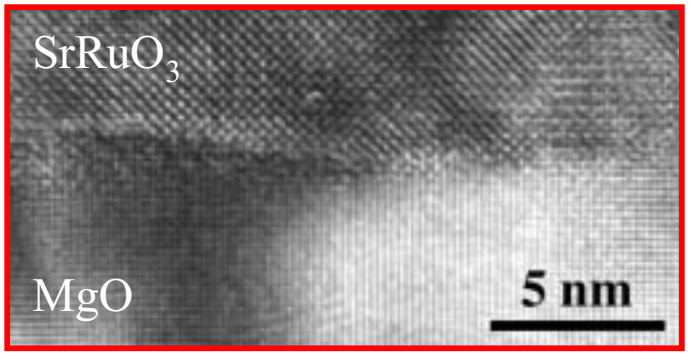
in-plane FWHM ~ 3.7° has been measured for $SrRuO_3$

$SrRuO_3$ grown on IBAD-MgO on Ni-alloy shows smooth surface and relatively large grain size

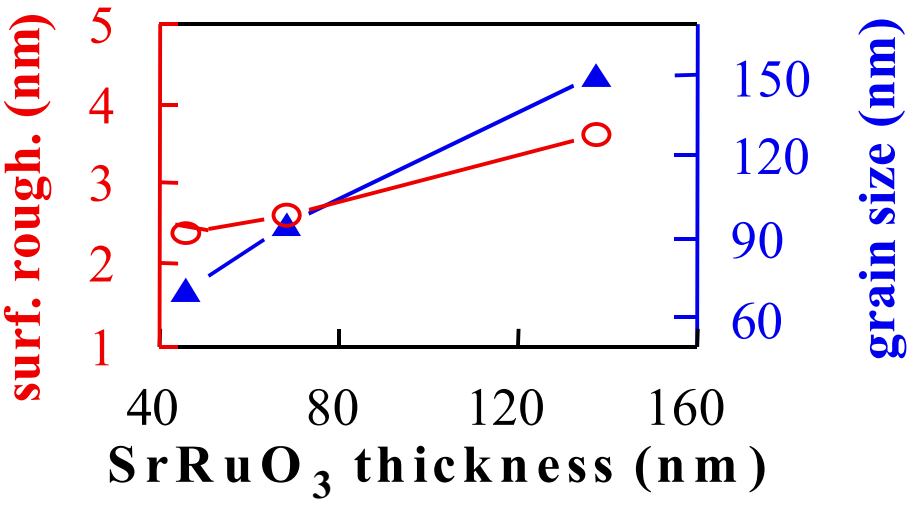
$SrRuO_3$ on IBAD-MgO on Ni-alloy



0 500 nm

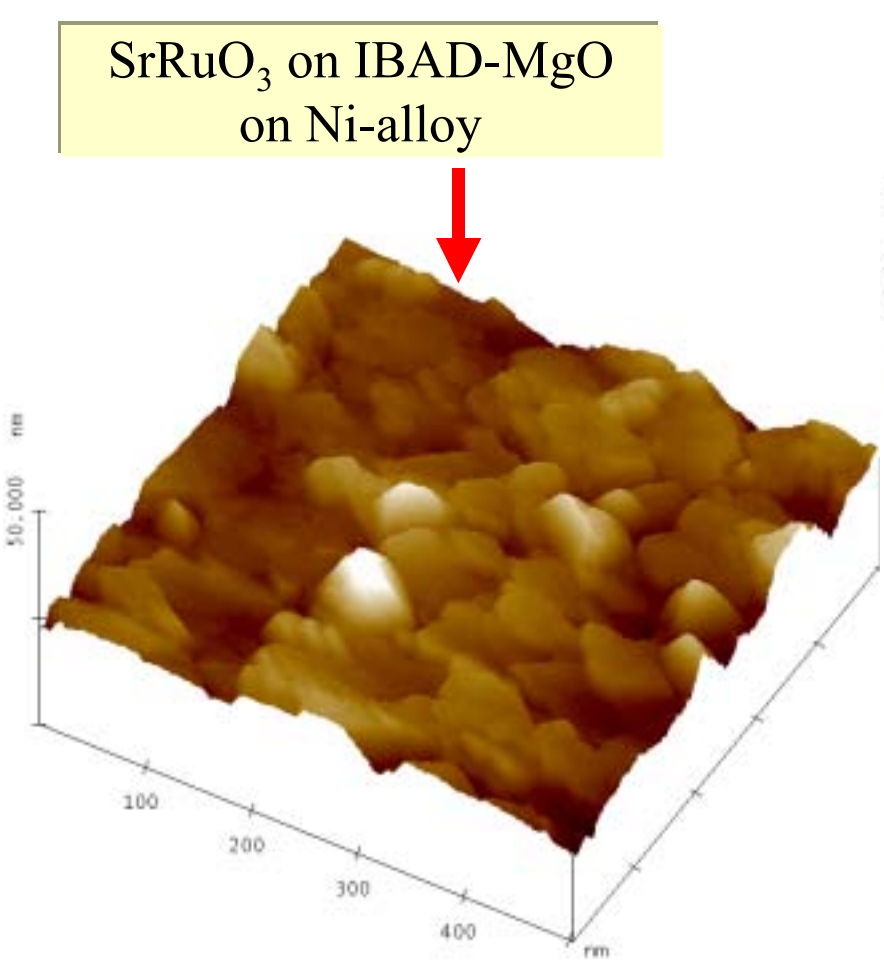


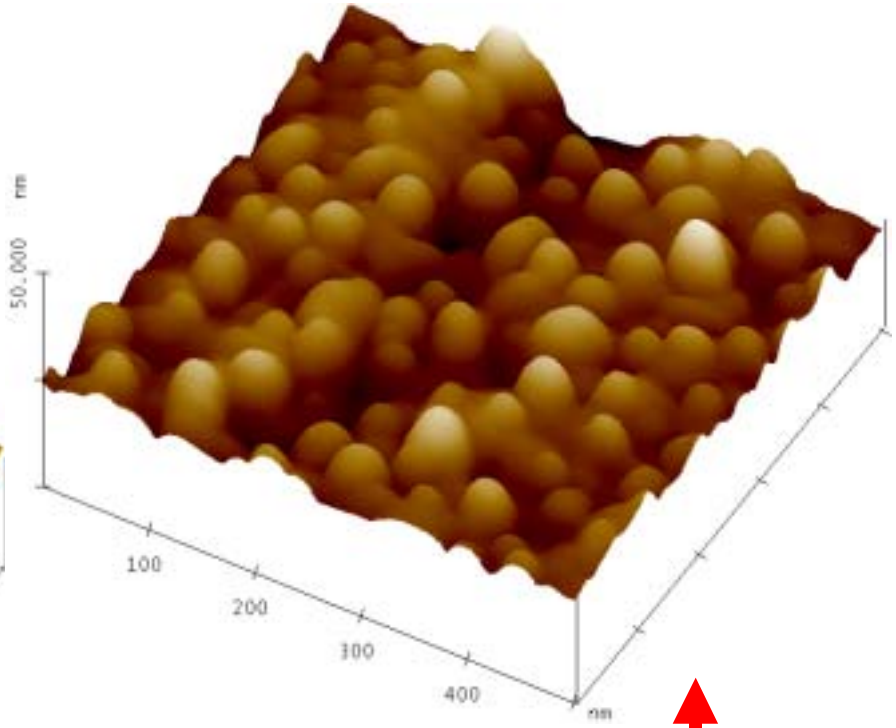
Clean interface between the MgO template and the $SrRuO_3$ buffer



$SrRuO_3$ epitaxially grown more favorably compared to $SrTiO_3$ on IBAD-MgO surface

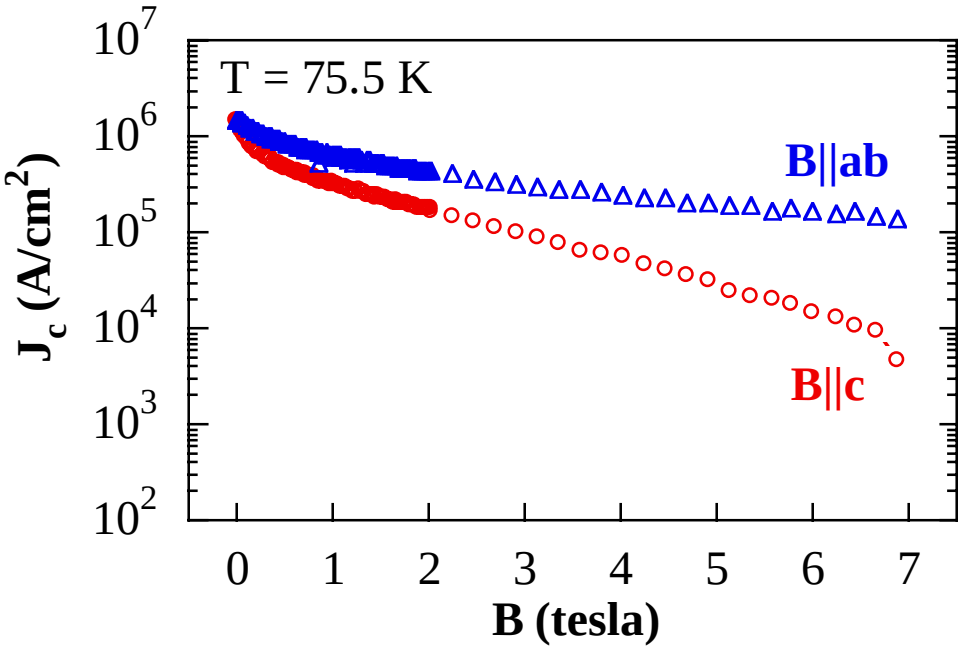
$SrRuO_3$ on IBAD-MgO on Ni-alloy

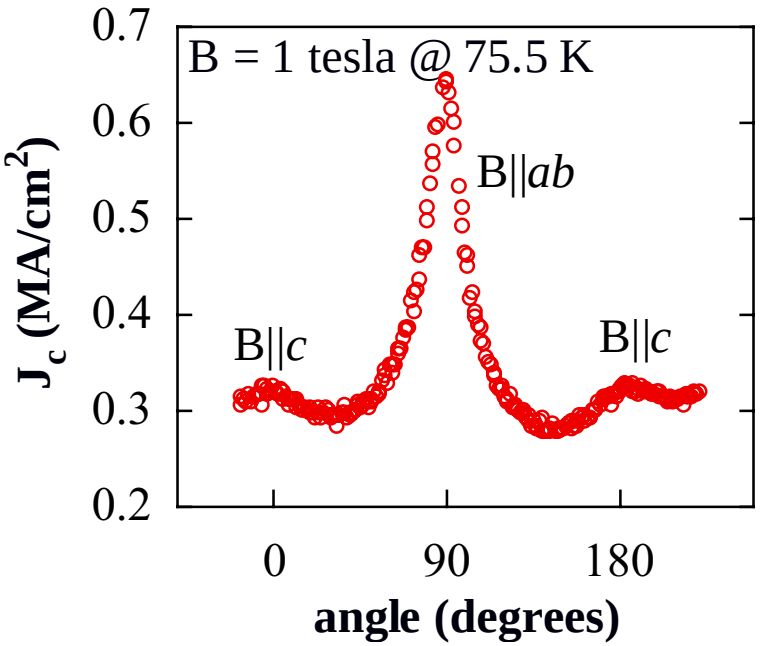




$SrTiO_3$ on IBAD-MgO on Ni-alloy

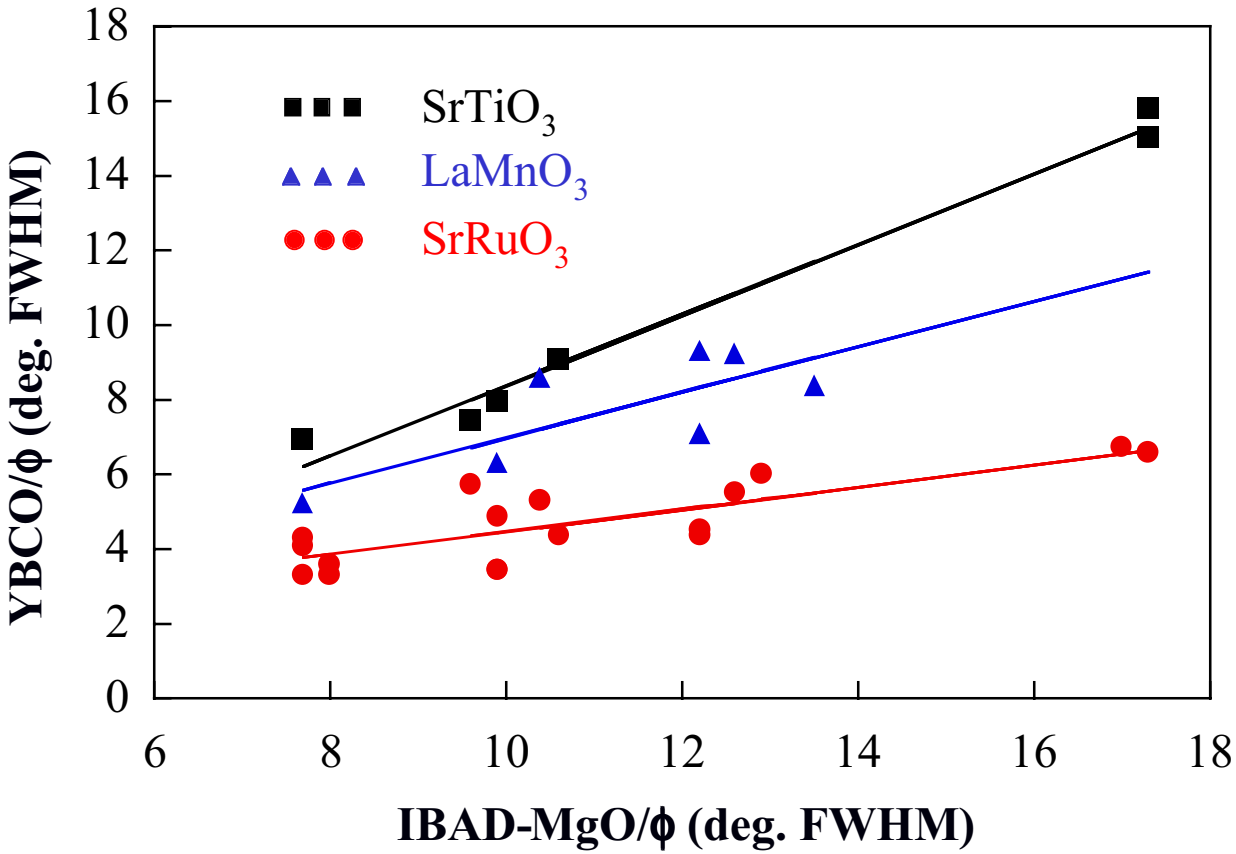
YBCO films on $SrRuO_3$/IBAD-MgO on Ni-alloy have typical field and angle dependent superconducting properties



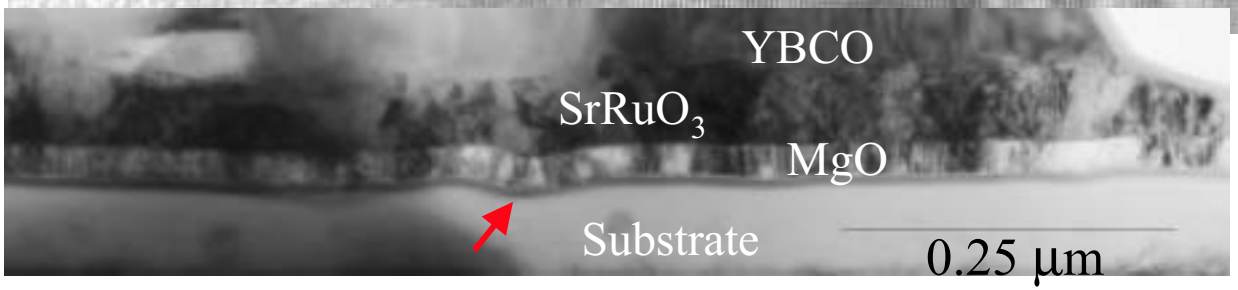


1.3 μm YBCO ⊂ J_c = 1.7 MA/cm^2
1.1 μm YBCO ⊂ J_c = 1.8 MA/cm^2

Much improved in-plane texture of YBCO when $SrRuO_3$ is used as a buffer on IBAD-MgO template

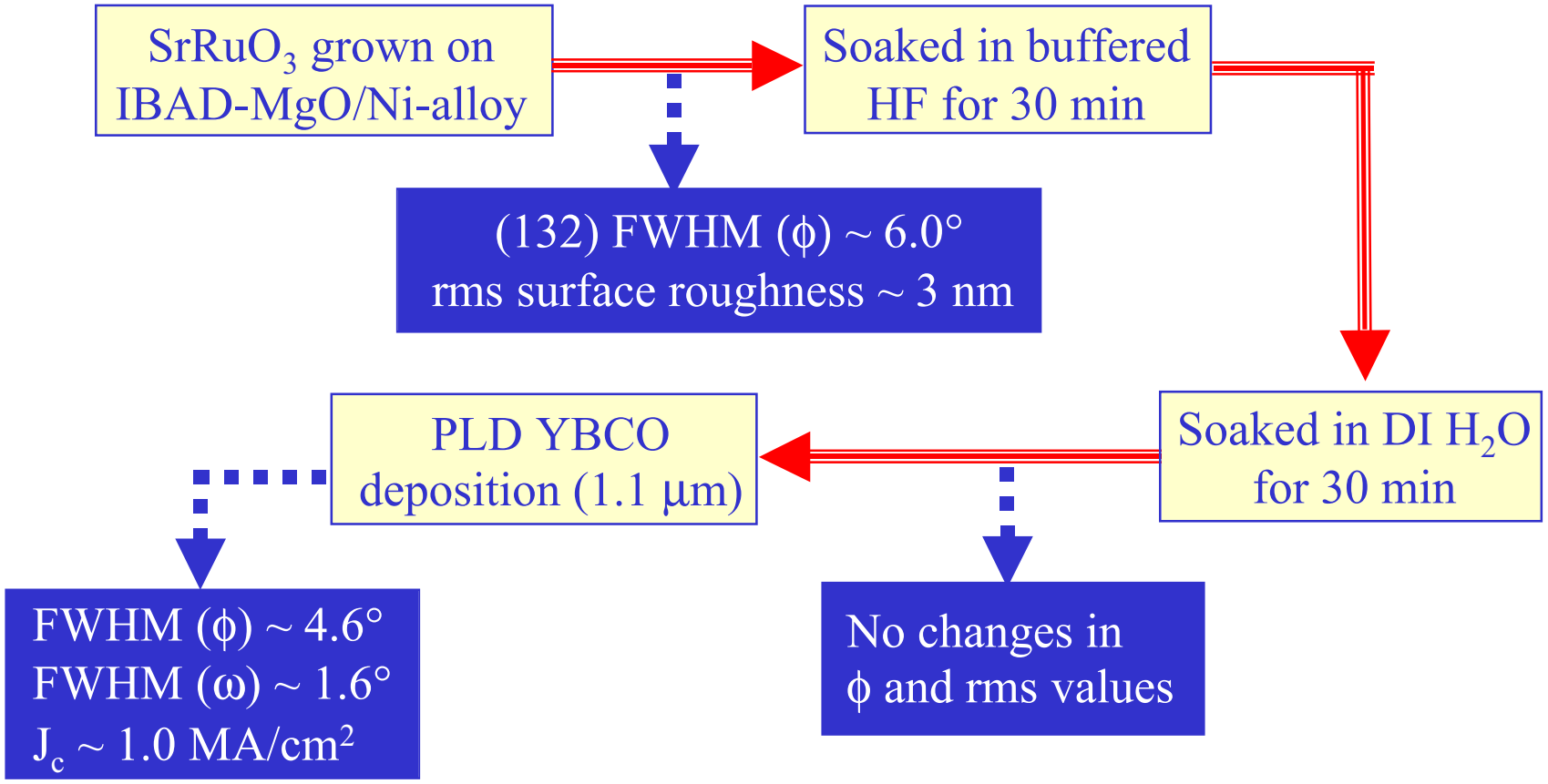


$SrRuO_3$ planarizes surface irregularities on the IBAD-MgO template on Ni-alloy substrate



The $SrRuO_3$ smoothes out the variations in the IBAD-MgO on Ni-alloy.

$SrRuO_3$ on IBAD-MgO exhibits superb chemical stability in the presence of hydrofluoric acid and water



Summary: $SrRuO_3$ proved to be an excellent buffer on IBAD-MgO for coated conductors

- Structurally compatible with YBCO conductor and MgO
- Chemically stable at processing conditions
- Insensitivity to the in-plane texture of the MgO
- Much improved YBCO in-plane texture over MgO
- Smooth out the variations in the MgO on Ni-alloy
- Superb chemical stability in the presence of hydrofluoric acid and water
- By using a single buffer $SrRuO_3$ with a thickness of less than 50 nm, $J_c > 1$ MA/cm^2 has been *routinely* achieved for over 1 μm thick YBCO films on IBAD-MgO on Ni-alloy.